SUPERVISED-MACHINE LEARNING FOR INTELLIGENT COLLISION AVOIDANCE DECISION-MAKING AND SENSOR TASKING

2018 NASA GODDARD WORKSHOP ON ARTIFICIAL INTELLIGENCE

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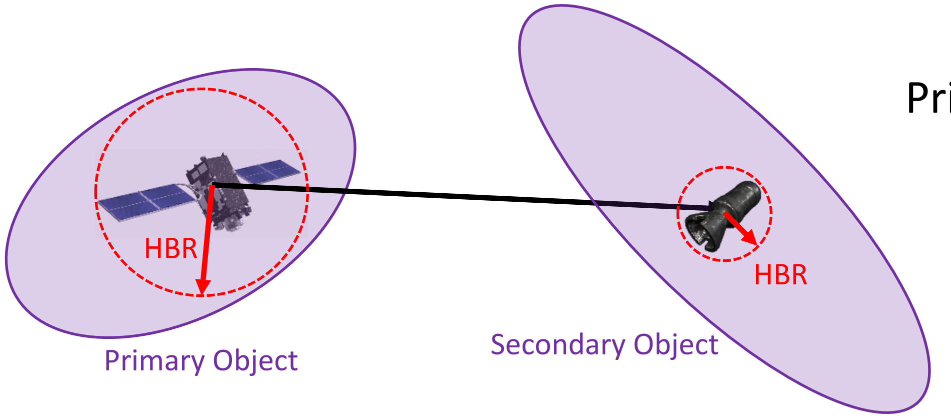
Background and Motivation



Primary and Secondary objects in a close encounter are described by:

- -Position (Relative Position)
- -Velocity
- -Covariance matrix (region of uncertainty)
- -Hard-body radius (HBR) (circumscribing radii)

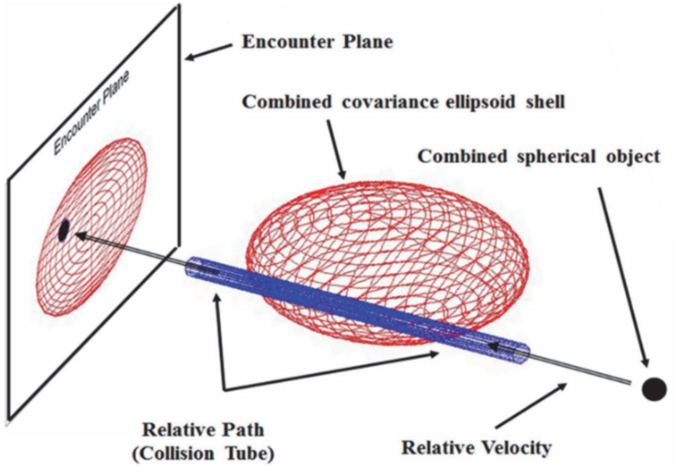
$$Pc = \frac{1}{\sqrt{8\pi^3}\sigma_x\sigma_y\sigma_z}\iiint_{Vti}^{Vtf} exp\left[\frac{-x^2}{2(\sigma_x)^2}+\frac{-y^2}{2(\sigma_y)^2}+\frac{-z^2}{2(\sigma_z)^2}\right]dxdydz$$

Pc computed from integrating the combined covariance matrix over the total HBR volume swept.

If relative motion in the encounter region is linear, the problem can be reduced to a two-dimensional integral by integration and projection.

$$Pc = \frac{1}{2\pi\sigma_x\sigma_y}\int_{-HBR}^{HBR}\int_{-\sqrt{HBR^2-x^2}}^{\sqrt{HBR^2-x^2}} exp\left[(-\frac{1}{2})\left\{\left(\frac{x+x_m}{\sigma_x}\right)^2+\left(\frac{y+y_m}{\sigma_y}\right)^2\right\}\right]dxdy$$

-This "2D" Pc is the primary method currently used in the field of space situational awareness.

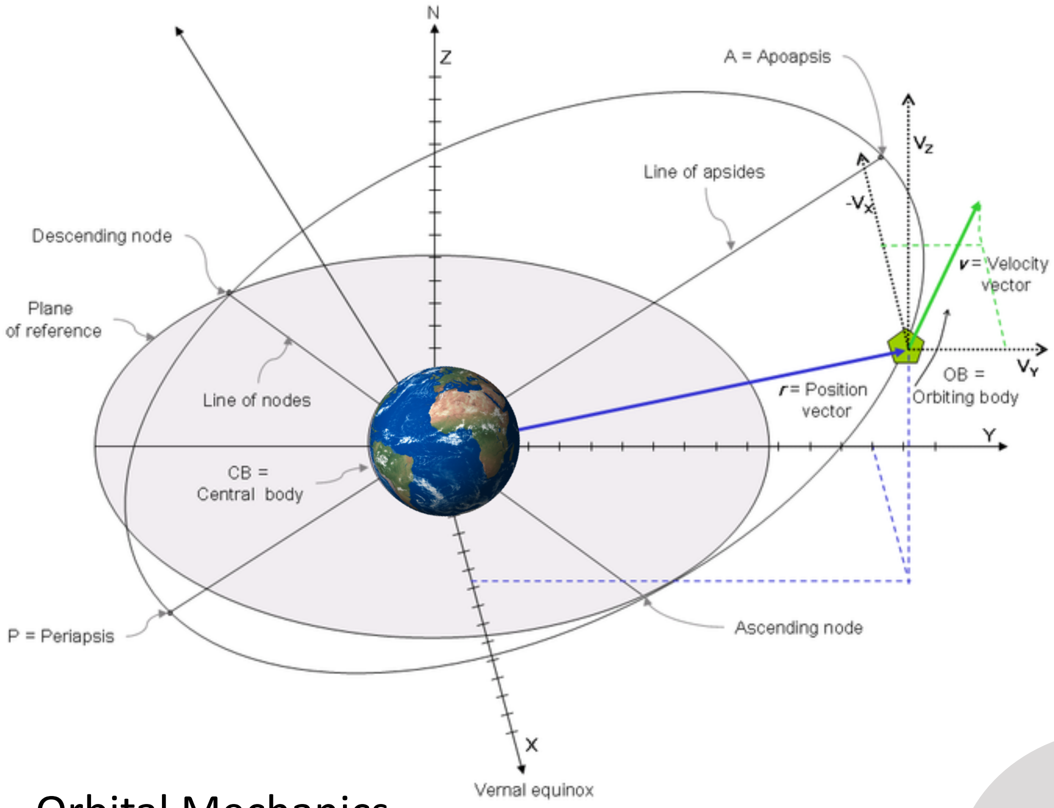


GOAL: Investigate and construct an autonomous architecture using physics-based statistical parameters via supervised-machine learning and deep neural networks for *intelligent* and *reliable autonomous* satellite collision avoidance decision-making.

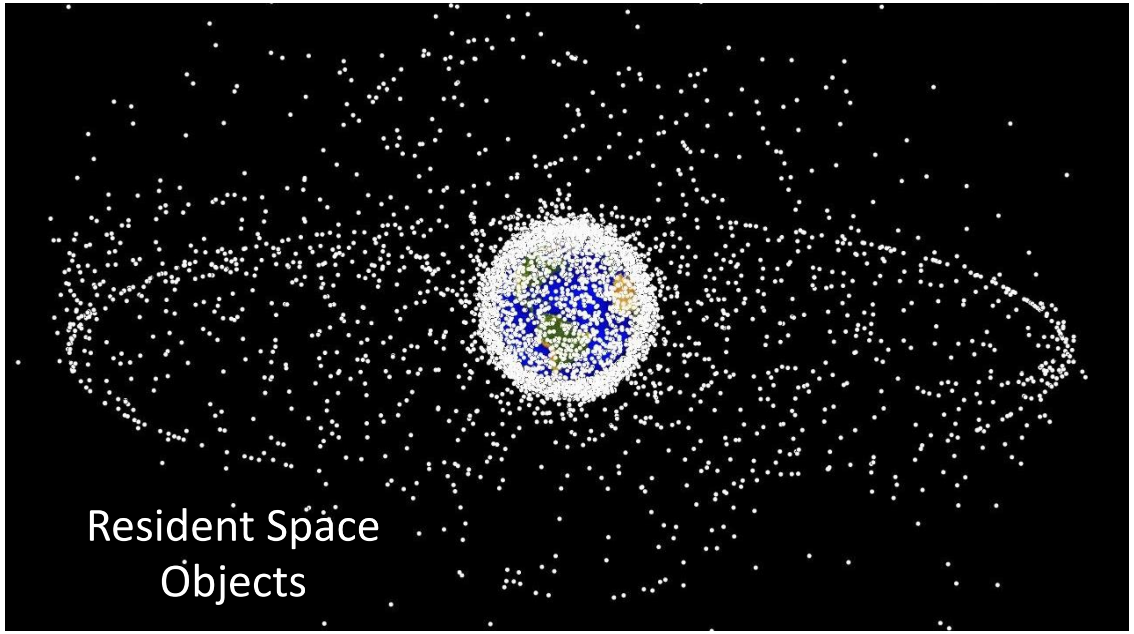
Astrodynamics

Newton's laws of universal gravitation

and laws of motion

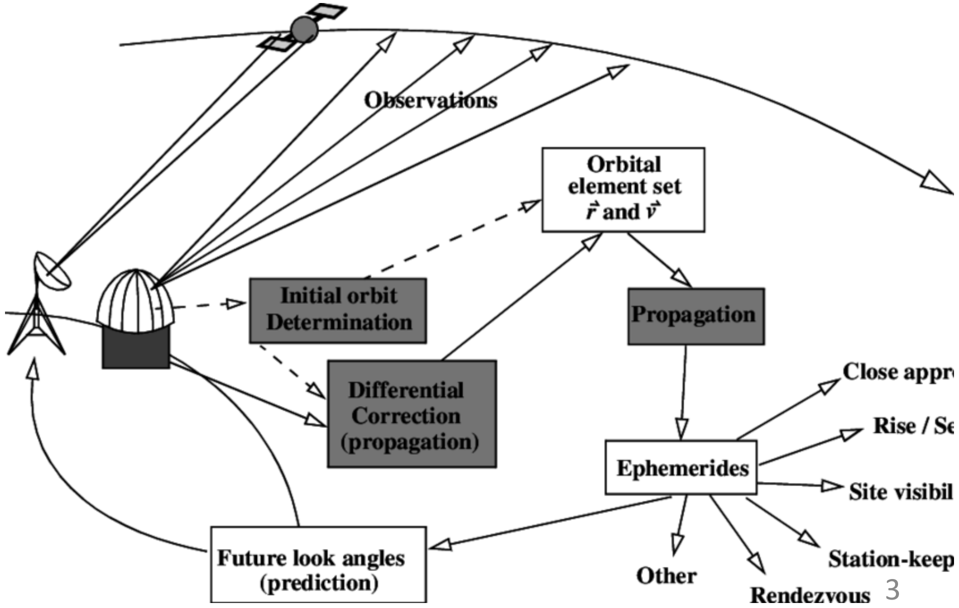


Orbital Mechanics



Navigation OR
Orbit
Determination

Sensor tasking

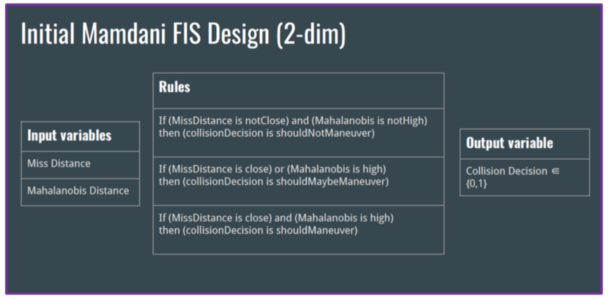


Machine Learning for Space Situational Awareness Using Fuzzy Inference System (FIS)

Two spacecraft at Time of close approach (TCA) (500 simulated cases)

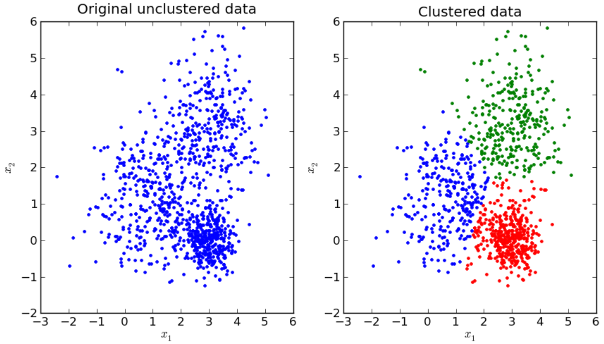
Statistical Parameters
Probability of Collision
Miss Distance
Mahalanobis Distance
Bhattacharyya Distance
Kullback-Leibler Distance etc.

Summer Internship work (Partial) by
Evana Gizzi (Tufts University)
Mitch Zielinski (Purdue University)



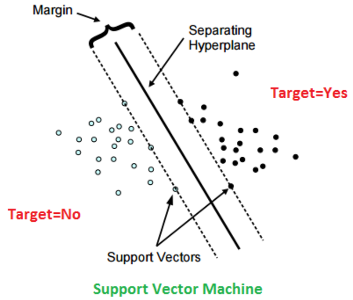
Fuzzy-Inference System (FIS) Logic Design

K-means

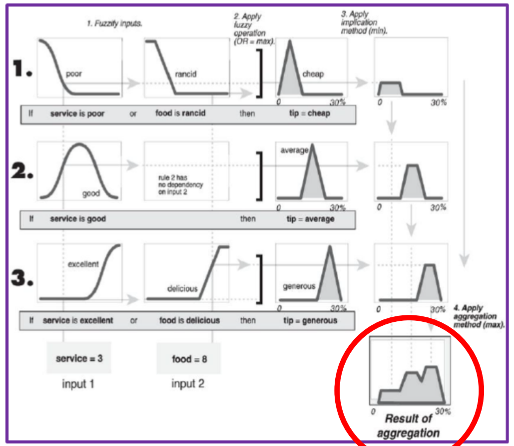


Partition **N** observations into **K** clusters.

SVM-Support Vector Machines

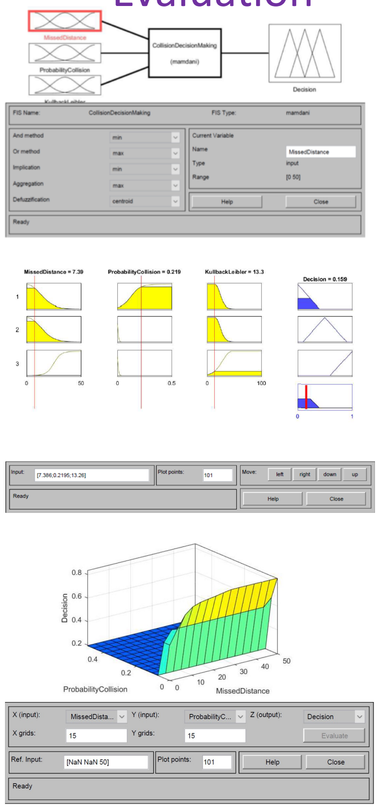


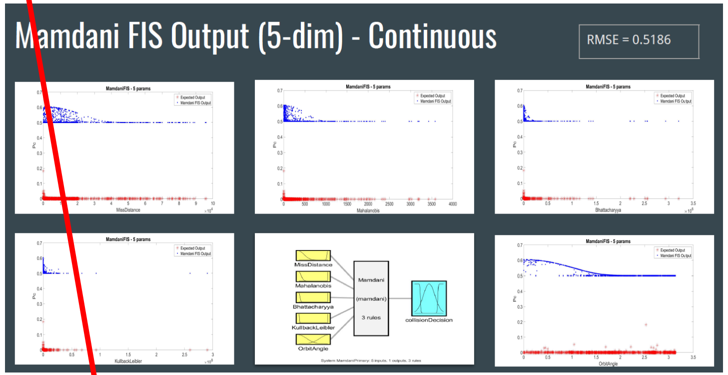
Separation into **K** groups with the widest gap possible



FIS Input-Output Determination

FIS Evaluation



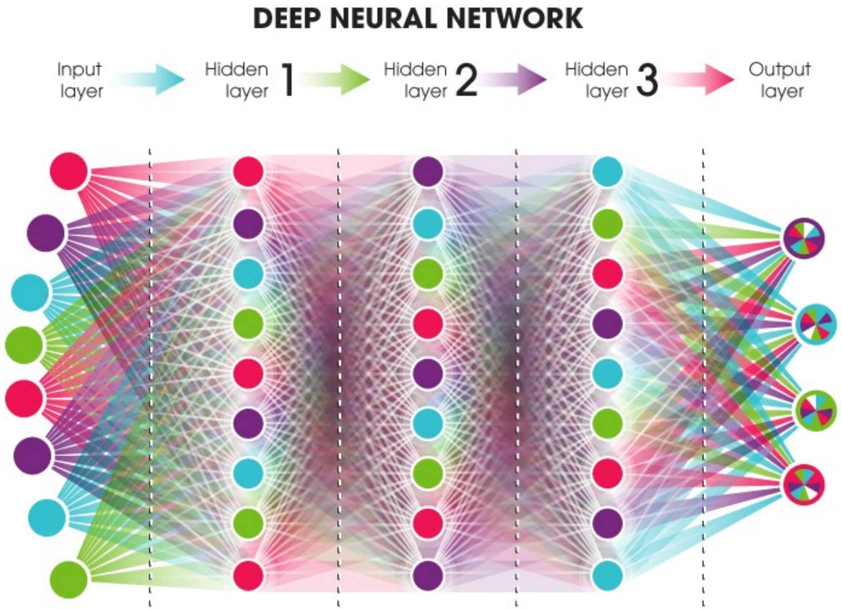


Non-definitive output

Machine Learning for Space Situational Awareness Using Deep Neural Networks

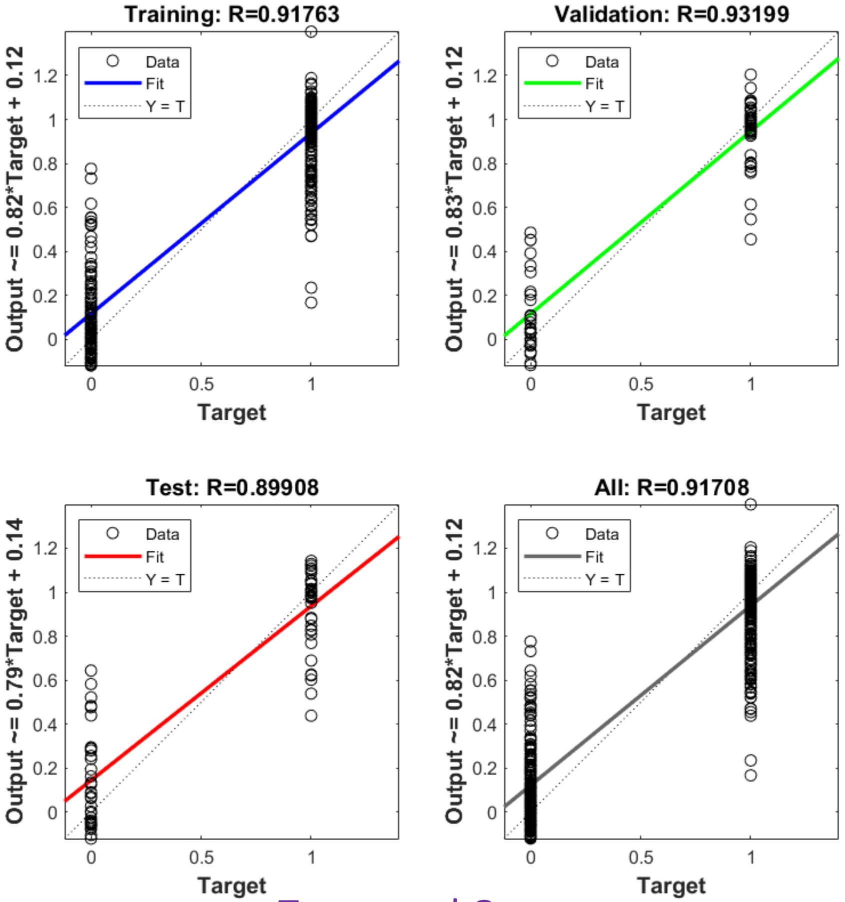
Two spacecraft at Time of close approach (TCA) (500 simulated cases)

Statistical Parameters
Probability of Collision
Miss Distance
Mahalanobis Distance
Bhattacharyya Distance
Kullback-Leibler Distance etc.



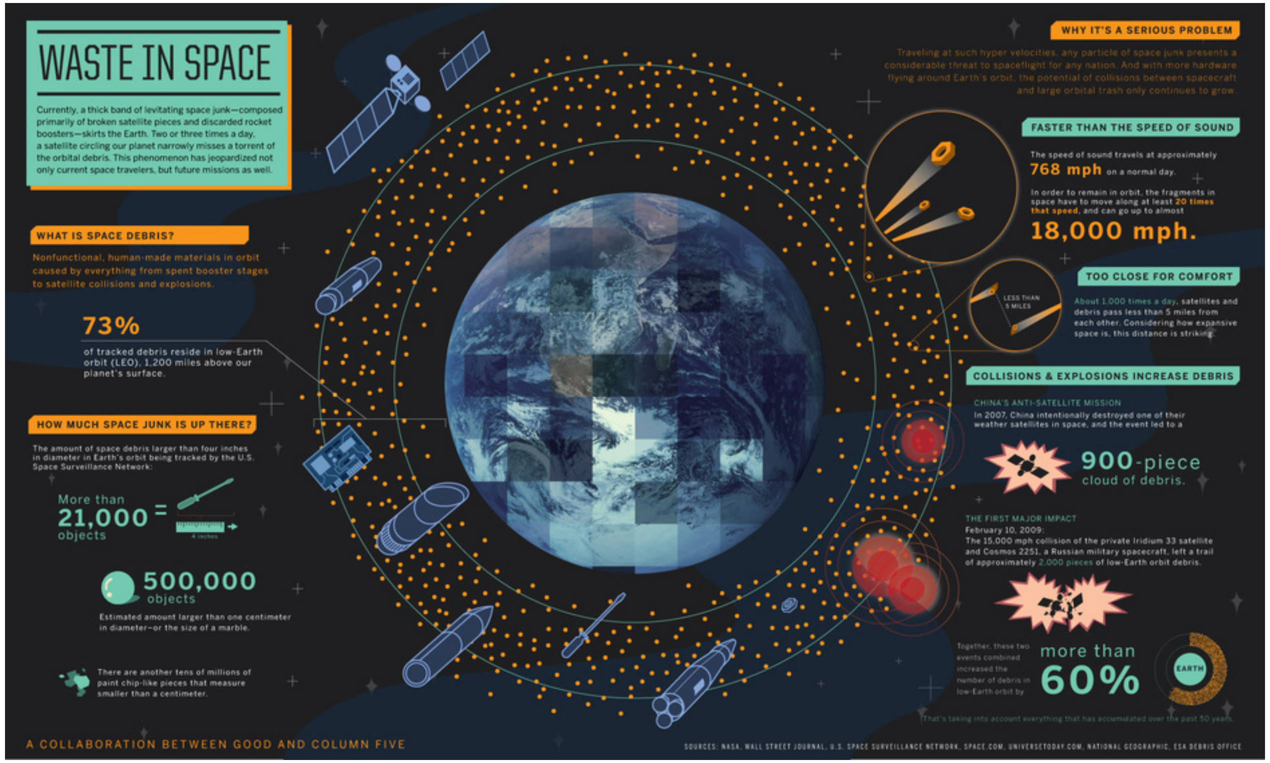
A Deep Neural network has: Nodes and weights operated by nonlinear functions

Preliminary overall performance was ~92% accurate



Target and Output
0 - Safe
1 - Close approach

Artificial Intelligence for Space Situational Awareness and Space Traffic Management



Intelligent data analytics can help us understand and augment problem-solving techniques beyond our current capabilities.

(1) https://media.defense.gov/2017/Oct/04/2001822339/-1/-1/0/171004-F-O3755-1003.JPG
(2) https://www.isdi.education/es/isdigital-now/blog/actualidad-digital/dealing-big-data-and-analytics

THANK YOU

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  - PI: Dr. Alinda Mashiku, NASA GSFC Navigation and Mission Design Branch (595)
  - Co-PI: Prof. Carolin Frueh, Purdue University School of Astronautics and Astronautics and
  - Co-PI: Dr. Nargess Memarsadeghi, NASA GSFC Science Data Management Branch (586)

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  - Evana Gizzi : Tufts University
  - Mitch Zielinski : Purdue University

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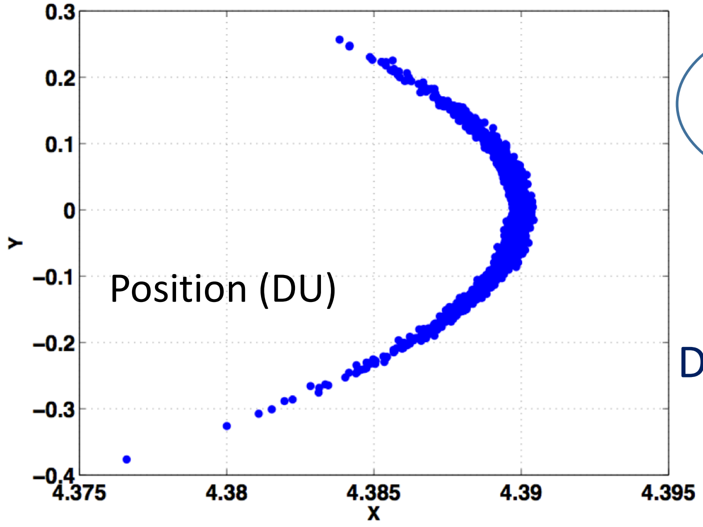
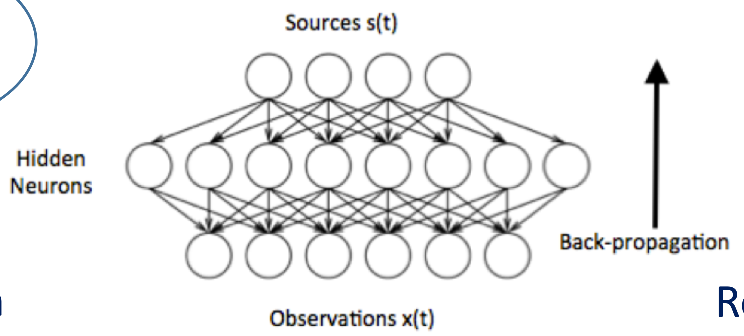
Machine Learning for State Uncertainty Characterization



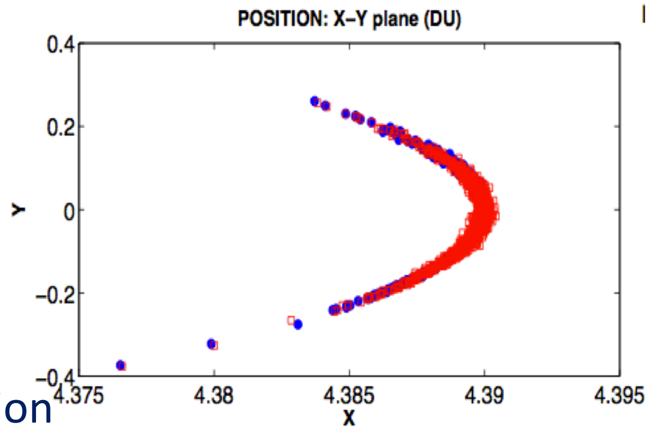
Retain Non-Gaussian Information

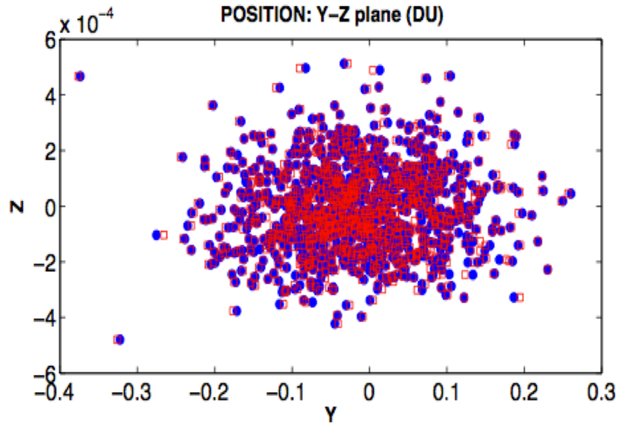
Data Decorrelation

Neural Network



Data Reconstruction





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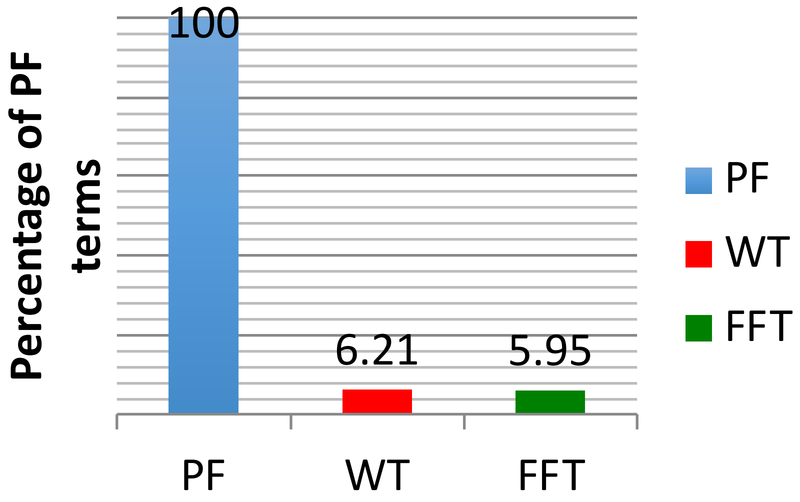
Fast-Fourier and Wavelet Transforms and Inverses

Monte Carlo samples for a spacecraft's position uncertainty characterization (**<u>Generated using a Particle Filter (PF)</u>**)



Compressed data with retained information content

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